Gap Excitations and Series Loads in Microstrip Lines: Wide Band Equivalent Network Characterization with Application to THz Circuits

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Approximate quasi-static formulations exist for deriving the propagation constant, characteristic impedance, and lumped element equivalent circuit of various microstrip discontinuities [1] (and many others). At submillimeter wavelengths typical gap discontinuities, which might contain diodes or active elements, cannot be viewed as simple lumped elements. Planar diodes at 2.5 THz for example [2], are typically fabricated with anode finger lengths comparable to a wavelength. Thus, apart from modelling the diodes themselves, the connection with their exciting elements (antennas or microstrip) gives rise to parasitics which cannot be modeled by invoking quasi-static lumped elements. Full wave or strictly numeric approaches [3] (and many others) can be used but at the expense of generality of the solution and the CPU time of the calculation. In this paper an equivalent network is derived that accurately accounts for large discontinuities (with respect to a wavelength) without suffering from the limitations of more available numeric techniques.

An equivalent network representation of the finite gap, which is both physically interpretable and accurate, is derived that evaluates the input impedance of the microstrip gap viewed as a generator. The derived network parameters are obtained by evaluation of the electric current distribution on an equivalent infinitely extended microstrip that is gap excited. The method is based on deriving an approximate solution of the Integral Equation (IE) representing the null of the total electric field along the microstrip axis. The approximation consists in the assumption of separability between the transverse and the longitudinal space dependence of the electric current, and in the assumption of a given (but respecting edge-singularity) transverse dependence of the electric current. Despite the simplicity of the solution, the final results agree well with those obtained using a rigorous full-wave analysis over a wide frequency range. A spectral expression allows the determination of the guiding mode wave number. The evaluation of the residue contributions associated with this pole allows us to derive an equivalent transformer that accounts for the gap launching coefficient on the equivalent transmission line of the main quasi TEM mode in the microstrip. By subtracting the current associated with the main mode on the infinite line from the total current in the feed zone, a fringing current that is confined to the region surrounding the gap is obtained. From this current an admittance is derived that accurately represents the effects of the finite gap and the surrounding grounded dielectric slab. It will be shown that for dimensions that are typical of a series connected diode at submillimeter wavelengths, the gap admittance may deviate from a lumped capacitance and not only become inductive but present at the same time a significant real part. Neglecting this gap effect, or representing it by a purely quasi-static approximation is totally inadequate, while a full wave solution is dramatically more involved and cumbersome than the procedure presented here. It should also mentioned that the calculation of the equivalent network parameters for the gap is extremely fast and can be applied to any stratified dielectric medium.

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[3]. P.B. Katehi, N.G. Alexopoulos "Frequency Dependent Characteristics of Microstrip Discontinuities in Millimeter-Wave Integrated Circuits," *IEEE Trans. Microwave Theory & Tech.*, v. MTT 33, pp. 1029-35, Oct. 1985.